

March 29, 2023
Date

David G. Gannon
Express Mail Label No.
EL 846165056 US

- 1 -

Information Storage Apparatus and Information Reproducing Method

BACKGROUND OF THE INVENTION

(i) Field of the Invention

The present invention relates to an information storage apparatus and an information reproducing method for reproducing information recorded on an information storage medium.

(ii) Description of the Related Art

As a high-density information storage medium for recording and reproducing sound data or image data, an optical storage medium or a magnetic storage medium is known. Spiral or concentric tracks are typically provided on such an information storage medium, and these tracks are divided into a plurality of regions which are generally called sectors. Also, there is known an information storage apparatus which records information by writing marks in these sectors by a magnetic field or heat or an information storage apparatus which reproduces information by reading the marks by the magnetic field or heat.

With recent improvement in the computer technology, a data size or a quantity of sound data or image data to be used is increasing and enhancement of recording density of the information storage medium is eagerly desired. Narrowing the track pitch is demanded in order to greatly improve the recording density of the information storage

medium.

As a technique for narrowing the track pitch, there is proposed one called land and groove recording by which information is recorded on both flute-like grooves and protruding lands alternately provided on the storage medium.

Fig. 1 is a view showing sectors on an information storage medium adopting the land and groove recording.

Fig. 1 illustrates three grooves 1, 2 and 3 and two lands 4 and 5 alternately provided with respect to these grooves 1, 2 and 3. Both the grooves 1, 2 and 3 and the lands 4 and 5 are used as tracks, and a plurality of sectors are provided to each track. Numbers for differentiating the sectors are given to these multiple sectors. For example, the -10th sector Sct-10, the -ninth sector Sct-9, the -eighth sector Sct-8, ..., the 10th sector Sct10, the 11th sector Sct11, the 12th sector Sct12, ..., the 30th sector Sct30, the 31st sector Sct31, the 32nd sector Sct32, ... are provided on the three grooves 1, 2 and 3 in the drawing, and the 0th sector Sct0, the first sector Sct1, the second sector Sct2, ..., the 20th sector Sct20, the 21st sector Sct21, the 22nd sector Sct22, ... are provided to the respective two lands 4 and 5. That is, serial numbers are given to respective sectors provided in one track, and numbers given to a sector are different by 10 from those given to another sector adjacent to the former in a transverse direction of the tracks. Further, the number given to the sector is increased toward the central direction (inner direction) of

the information storage medium and decreased toward the outer peripheral surface (outer direction).

In this manner, both the grooves and the lands are used as tracks in the land and groove recording. Therefore, the track pitch in a technique such that only lands are used as tracks is, e.g., $0.9\text{ }\mu\text{m}$, whereas the track pitch in the land and groove recording is an extremely narrow pitch, i.e., $0.65\text{ }\mu\text{m}$. The recording density can be greatly increased if the linear recording density remains unchanged. Accordingly, the above-described technique is very important for realizing the high-density recording.

However, if the land and the groove recording and the like is adopted to greatly narrow the track pitch, when reading a mark on a given track, cross talk caused due to a mark on a track adjacent to that track prevents the mark from being read. For example, when reading the mark recorded in the 11th sector Sct11 in Fig. 1, cross talk occurs due to the mark in the first sector Sct1 or the mark in the 21st sector Sct21.

Fig. 2 is a graph showing an example of cross talk.

The upper part in Fig. 2 shows a signal waveform of a read signal obtained when performing reading with respect to a sector in erase state having no mark therein. A mark is written in a sector adjacent to the sector in erase state in a transverse direction of the tracks.

Further, the lower part of the Fig. 2 graph shows a gate signal indicative of a significant part in the read

signal. In the signal waveform of the read signal shown in the upper part of the graph, only a portion corresponding to a time interval during which the waveform of the gate signal shown in the lower part rises is a significant signal waveform.

A flat waveform and a spike-like waveform exist in the signal waveform of the read signal, and the flat waveform is indicative of a signal caused due to a sector in erase state and the spike-like waveform is indicative of cross talk owing to a sector on an adjacent track. The signal intensity of such cross talk may be strong such that the signal is hardly differentiated from an original read signal. In such a case, a mark in a sector as a read target is prevented from being read.

Although the above-described problem prominently occurs in an optical disk device adopting the land and groove recording in particular, it occurs not only in such a device but it is typically generated in an information storage apparatus for reproducing information on an information storage medium having a narrow track pitch.

SUMMARY OF THE INVENTION

In view of the above-described drawback, an object of the present invention is to provide an information storage apparatus and an information reproducing method capable of reading marks without being disturbed by cross talk even if a track pitch is narrow.

Adopting the technique according to the present invention enables normal reading of a mark even if a track pitch is narrowed, and realization of high density of an information storage medium can be hence advanced.

5 To this end, an information storage apparatus according to the present invention comprising:

10 a mark reading section for reading a mark written on an information storage medium, said information storage medium which has a recording area divided into a plurality of regions, on which information is recorded by writing a mark, and from which information is reproduced by reading the recorded mark; and

15 a recording state changing section for changing a recording state in an adjacent region situated next to a failed region from which said mark reading section fails to read a mark among a plurality of said regions, if said mark reading section fails to read said mark, so that cross talk caused due to said adjacent region can be reduced,

20 said mark reading section again reading a mark in said failed region after changing a recording state in said adjacent region by said recording state changing section.

25 The term "region" used herein may be a generally called sector, a block consisting of a plurality of sectors, or multiple divided sectors. Further, the sector may be arclike or linear.

According to the information storage apparatus of the present invention, since the recording state in an

adjacent region is changed so that cross talk caused due to the adjacent region can be reduced, a mark in a failed region can be normally read.

The recording state changing section of the information storage apparatus according to the present invention may erase a mark written in an adjacent region, or it may write on an overwriting basis in an adjacent region a mark generating lower cross talk than that caused due to a mark written in that adjacent region.

Here, "a mark generating lower cross talk" may be any mark as long as cross talk is substantially lower than that of an existing mark. For example, it may be a mark obtained by rewriting under appropriate write conditions an existing mark having cross talk increased due to a change in a mark form with passage of time after writing, or a mark having a length shorter than that of an existing mark in an adjacent region, or a mark having a width narrower than that of the existing mark. Moreover, a mark having a narrower width than that of an existing mark can be readily realized by writing a mark with power weaker than that used for writing the existing mark.

According to the information storage apparatus of the present invention, it is preferable that the recording state changing section changes a recording state in an adjacent region after evacuating information recorded in the adjacent region and restores the evacuated information in the adjacent region after again reading a mark in a failed region

by the mark reading section.

If the information is recorded in the adjacent region, effacement of the information due to a change in the recording state can be avoided by evacuating and restoring the information before and after change of the recording state in the adjacent region.

Further, according to the information storage apparatus of the present invention, it is desirable that "said information storage medium includes an alternative region used in place of said region according to needs,

said recording state changing section performing evacuation of information recorded in said adjacent region to said alternative region and registration of use of said alternative region instead of said adjacent region before changing a recording state in said adjacent region."

Since use of the alternative region instead of the adjacent region is registered before changing the recording state, normal use of the information storage medium can be guaranteed even if a failure occurs in the adjacent region when changing the recording state and the like.

To achieve the above-described object, an information reproducing method according to the present invention comprising:

mark reading step of reading a mark written in an information storage medium, said information storage medium having a recording area divided into a plurality of regions, information being recorded by writing a mark in said region

and reproduced by reading said mark;

recording state changing step of changing a recording state in an adjacent region situated next to a failed region from which a mark fails to be read in said mark reading step among a plurality of said regions, if said mark reading step fails to read said mark, so that cross talk caused due to said adjacent region can be reduced; and

mark rereading step of again reading said mark in said failed region after changing a recording state in said adjacent region in said recording state changing step.

Although only a basic mode of the information reproducing method is disclosed herein in order to simply avoid tautological explanation, the information reproducing method includes various types of information reproducing method associated with each mode of the above-described information storage apparatus as well as the basic mode of the information reproducing method.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a view showing sectors on an information storage medium adopting land and groove recording;

Fig. 2 is a graph showing an example of cross talk;

Fig. 3 is a view showing an MO disk device incorporating a function as an embodiment of an information storage medium according to the present invention;

Fig. 4 is a view showing a DMA provided on an information storage medium;

Fig. 5 is a flowchart showing a first example of read retry processing;

Fig. 6 is a view showing marks having a long mark length;

5 Fig. 7 is a view showing marks having a short mark length;

Fig. 8 is a view showing marks having different mark widths;

10 Fig. 9 is a graph illustrating an advantage of a second example of first-class reduction processing;

Fig. 10 is a flowchart showing a second example of the read retry processing;

Fig. 11 is a flowchart showing a third example of the read retry processing;

15 Fig. 12 is a flowchart showing a fourth example of the read retry processing;

Fig. 13 is a flowchart showing a fifth example of the read retry processing; and

20 Fig. 14 is a flowchart showing a sixth example of the read retry processing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

25 An embodiment according to the present invention will now be described hereinafter. In the following description, terms "information" and "data" may not be differentiated from each other in some cases.

Fig. 3 is a view showing an MO disk device

incorporating a function as an embodiment of the information storage apparatus according to the present invention.

This MO disk device 100 uses a magnetic optical (MO) disk as an information storage medium 200, and a recording area of the information storage medium 200 is divided into such sectors as shown in Fig. 1. These sectors are an example of the regions according to the present invention. Further, a DMA (Defect Management Area) including spare sectors is provided in the information storage medium 200.

Fig. 4 is a view showing a DMA provided on the information storage medium.

A usual recording area 201 is provided in the annular form on the information storage medium 200, and DMAs 202 are provided along the inner periphery and the outer periphery of the recording area 201. The DMA 202 includes an alternative area consisting of a set of sectors used as backups of sectors included in the usual recording area 201, and use of a sector constituting an alternative area instead of a sector included in the regular recording area 201 is registered in the DMA 202. The sector constituting the alternative area is an example of the alternative region according to the present invention.

Fig. 3 is again referred to continue explanation.

The information storage medium 200 is held by a spindle motor 110. Revolution drive of the spindle motor 110 is controlled by an MPU (Micro Processor Unit) 120. The MPU 120 operates in accordance with a program stored in a non-

volatile memory 121 and utilizes a DRAM 122 as a working area.

Further, the MO disk device 100 is provided with a laser diode unit 130 and a laser beam having a predetermined intensity is emitted from the laser diode unit 130 during reproduction of information. The intensity of the laser beam is monitored by a monitor photodetector included in a detector group 131 and controlled by a write circuit 132 based on a monitor signal obtained by the monitor photodetector. The laser beam is incident upon the information storage medium 200 by an object lens 141 mounted on a positioner 140, thereby generating a reflected light ray associated with a mark recorded on the information storage medium 200. The reflected light ray is accepted by an ID/MO detector included in the detector group 131 to detect an ID signal and an MO signal. The ID signal and the MO signal are inputted into a read circuit 133 to be converted into reproduction data and a clock signal for data analysis. The laser diode unit 130 or the read circuit 133, therefore, constitutes an example of the mark reading section according to the present invention. The reproduction data obtained by the read circuit 133 is fed to an interface of a host device such as a computer through an optical disk controller 134.

On the other hand, at the time of recording information, recording data is supplied from the interface of a host device through the optical disk controller 134 and inputted together with a clock signal for writing data into the write circuit 132. In initialization (formatting) of the

information storage medium 200, formatted data is generated by the optical disk controller 134 to be inputted together with the clock signal for writing data into the write circuit 132. The write circuit 132 is controlled by the MPU 120 via a bus and operates in synchronism with the clock signal for writing data. Additionally, the write circuit 132 modulates the recording data and the formatted data to be converted into a laser diode drive current. The laser diode drive current is inputted into the laser diode unit 130 where a laser beam is emitted.

In recording information and formatting, an electric current is supplied to an electromagnet 150 so that a recording magnetic field is generated on the information storage medium 200. Information is recorded on the information storage medium 200 or the information storage medium 200 is formatted by the recording magnetic field and heat of the laser beam associated with the above-described write signal.

The electromagnet 150, the laser diode 130, the write circuit 132, the object lens 141, the MPU 120 and others constitute an example of the recording state changing section according to the present invention.

Further, the MO disk device 100 is provided with a lens actuator 142 for driving the object lens 141, and the above-mentioned positioner 140 having the object lens 141 and a lens actuator 142 mounted thereon moves along the surface of the surface storage medium 200. A track focus control

current is supplied to the positioner 140 and the lens actuator 142 by a driver 143 so that these members are controlled. The driver 143 outputs a track focus control current associated with a control signal inputted from a DSP (Digital Signal Processor) 144 via a D/A conversion circuit 145. The DSP 144 fetches and analyzes through an A/D conversion circuit 146 a tracking error signal (TES) and a focus error signal (FES) obtained by the detector group 131 and inputs a control signal based on a result of analysis to the driver 143.

A program showing the operation of the DSP 144 is also stored in the non-volatile memory 121, and the DRAM 122 is also used as a working space of the DSP 144.

Description will now be given as to read retry processing which is executed if mark reading has failed with reference to flowcharts.

Fig. 5 is a flowchart showing a first example of the read retry processing.

When the first example of the read retry processing starts, data in a sector adjacent to a failed sector from which the MO disk device 100 has failed to read a mark among the sectors on the information storage medium 200 is registered in an alternative area to be evacuated (step S101). First-class reduction processing which reduces cross talk caused due to the adjacent sector and involves destruction of data recorded in the adjacent sector is executed (step S102). The content of the first-class reduction processing will be

described later.

After execution of the first-class reduction processing, a mark in the failed sector is again read (step S103), and data in the adjacent sector is restored (step S104) to terminate the read retry processing.

According to such read retry processing, cross talk caused due to the adjacent sector is reduced to enable a mark to be normally read.

As the first-class reduction processing executed in the step S102, processing such as described below can be considered for example.

As a first example of the first-class reduction processing, erasing processing for erasing a mark written in the adjacent sector is possible. This erasing processing is a simple process and capable of assuredly reducing cross talk since a mark itself which can be a cause of cross talk is erased.

As a second example of the first-class reduction processing, there can be considered overwriting processing for writing on an overwriting basis in the adjacent sector a mark which generates cross talk having a lower level than that of cross talk caused by a mark written in that adjacent sector. In case of an MO disk, erasing and writing of a mark are performed as the overwriting processing, and verification of the mark may be also executed according to needs. As a mark to be written in the adjacent sector by this overwriting processing, a mark having a length or a width smaller than

that of a mark written in the adjacent sector can be considered for instance. As described above, the first-class reduction processing involves destruction of data recorded in the adjacent sector, and due to writing predetermined dummy data previously stored in, e.g., a ROM for overwriting the adjacent sector under predetermined writing conditions, a mark having a length or width smaller than that of an existing mark can be obtained. A length of a mark can be adjusted by a light emission time and the like of the laser diode 130 shown in Fig. 3. Further, the width of a mark can be adjusted by temperature control over a film of an MO disk, and this temperature control can be realized when the laser power of the laser diode 130 is controlled in accordance with an environment temperature.

At the step S102, when a mark is rewritten in accordance with the second example of the first-class reduction processing, a mark having a mark length or a mark width with which cross talk can be sufficiently reduced is written in the adjacent sector. However, when the mark has again failed to be read in the failed sector at the step S103, it is desirable that the laser power of the laser diode 130 is reduced by, e.g., a several % so that rewriting of the mark is again executed.

Fig. 6 is a view showing marks having a long mark length, and Fig. 7 is a view showing marks having a short mark length.

Figs. 6 and 7 show one groove 210, and two lands 220

and 230 sandwiching the groove 210, marks 240 and 250 being written on the groove 210. Here, a maximum value (for example, 8T) and a minimum value (for example, 2T) are determined for the length of the mark recorded on the information storage medium. The mark 240 shown in Fig. 6 is a mark having a long mark length close to the maximum value of the mark length, and the mark 250 illustrated in Fig. 7 is a mark having a short mark length close to the minimum value of the mark length. The mark having the maximum mark length is likely to produce cross talk most, and cross talk is hardly generated as the mark length of the mark becomes shorter. Accordingly, the mark 250 having a short mark length such as shown in Fig. 7 generates cross talk whose level is lower than that of cross talk produced by the mark 240 having a long mark length such as shown in Fig. 6.

Therefore, by writing the mark having the shorter mark length than the mark written in the adjacent sector for overwriting that adjacent sector, cross talk can be reduced.

Fig. 8 is a view showing marks having different mark lengths.

As similar to Fig. 6 or 7, Fig. 8 shows one groove 210 and two lands 220 and 230 sandwiching the groove 210. Here, three marks 260, 270 and 280 having different mark lengths are also shown on the groove 210. In regard to the laser power used when the three marks 260, 270 and 280 are respectively written, the laser power used when the mark 260 having the narrowest mark width is written is weakest,

whereas the laser power used when the mark 280 having the widest mark width is written is strongest. Additionally, as to the level of cross talk due to each of the three marks 260, 270 and 280, the level of cross talk due to the mark 260 having the narrowest mark width is lowest, whereas the level of cross talk due to the mark 280 having the widest mark width is highest.

Therefore, cross talk can be reduced by writing the mark having the narrower mark width than that of the mark written in the adjacent sector for overwriting that adjacent sector. Such a mark having the narrow mark width can be realized by overwriting the mark by using power weaker than that used when writing the mark in the adjacent sector. It is to be noted that write power for each sector may be stored and a mark may be overwritten by power weaker than that write power. Alternatively, a mark may be overwritten with power lower than current appropriate power for simplification. The appropriate power is updated with a predetermined timing.

Fig. 9 is a graph illustrating the advantage of the second example of the first-class reduction processing.

The horizontal axis of this graph represents power used when the mark is written, and the vertical axis of the same indicates an error rate of the read error generated when reading a mark in a sector adjacent to a sector in which the mark is written. Further, a line chart 310 with black squares represents measurement results relative to the long mark 240 shown in Fig. 6, and a line chart 320 with outline

squares represents measurement results relative to the short mark 250 illustrated in Fig. 7.

5 An allowable level of the error rate is typically approximately 10^{-3} , and both the error rate indicated by the line chart 310 with black squares and the error rate indicated by the line chart 320 with outline squares become equal to or far below the allowable level when the power is low to some extent. Accordingly, by overwriting a mark in the adjacent sector with the power which is low to some extent, normal mark reading is assured in a failed sector right next to the adjacent sector.

10 Moreover, the upper limit of the power range indicating the error rate obtained when the line chart 320 with outline squares is not more than the allowable level exceeds the upper limit of the power range indicating the error rate obtained when the line chart 310 with the black squares is not more than the allowable level. Therefore, even if the power used for writing the mark is strong, writing a short mark for overwriting the adjacent sector can assure normal mark reading in a failed sector right next to the adjacent sector.

20 If a factor which has caused reading of a mark in the failed sector to fail is cross talk, the possibility of restoration by the first-class reduction processing can be considered to be 90% to 100%.

25 Although cross talk of the adjacent sector can be reduced by the first-class reduction processing in this

manner, data recorded in the adjacent sector is destroyed in the first-class reduction processing.

On the other hand, according to second-class reduction processing described below, cross talk of the adjacent sector is reduced and data recorded in the adjacent sector can be maintained.

Generally, data recorded in a sector is represented by a length or an interval of a mark written in that sector, and it is often the case that a width of the mark is independent of data. Therefore, in the second-class reduction processing, a mark which has a length or an interval equal to those of a mark written in an adjacent sector, has a width narrower than that of the mark and is capable of being normally read is written on an overwriting basis in that adjacent sector. As a result, cross talk of the adjacent sector can be reduced, and data recorded in the adjacent sector can be maintained.

It can be considered that such second-class reduction processing can be realized by simply rewriting a mark in the adjacent sector with laser power suitable for writing the mark. That is because reading a mark in the failed sector is prevented by cross talk caused due to a mark in the adjacent sector, namely, it can be considered that the mark in the adjacent sector has a width larger than that of a mark written with the appropriate laser power.

Such a mark having a large mark width can be generated under conditions such as described below.

Since a width of a mark written in an MO disk changes in accordance with a temperature of a film or an intensity of a recording magnetic field of the MO disk, laser power appropriate for writing a mark is determined in accordance with an environment temperature or an intensity of a recording magnetic field. However, if the environment in which a mark in the adjacent sector is written is close to an allowable limit, a mark having a large mark width may be possibly written even if the mark is written with the appropriate laser power.

Moreover, a size of a written mark is not fixed, and there is known a phenomenon such that a size of a mark is increased with lapse of time. Such a phenomenon may possibly cause a mark with a large width to be generated in the adjacent sector when reading a mark in the failed sector even if the mark in the adjacent sector is written with a sufficiently small width.

The mark with the large mark width generated in such a circumstance is rewritten with laser power appropriate for writing the mark at the present time to become a mark having a sufficiently small mark width, and it can be considered that cross talk can be sufficiently reduced. However, when secure reduction in cross talk is desired, laser power which is lower than the appropriate laser power by a several % may be adopted for example, or laser power may be reduced multiple number of times within a range enabling writing until rereading in the failed sector proves successful.

It can be considered that the possibility of restoration by such second-class reduction processing is 90% to 100%.

Fig. 10 is a flowchart showing the second example of read retry processing.

In the second example of the read retry processing, the above-described second-class reduction processing is executed (step S201), and a mark in the failed sector is again read (step S202) so that the read retry processing is terminated without making any change.

In the above-mentioned second-class reduction processing, since data in the adjacent sector is maintained, evacuation and restoration of data in the adjacent sector are unnecessary.

Fig. 11 is a flowchart showing the third example of read retry processing.

Upon starting the third example of the read retry processing, data in the adjacent sector is registered in the alternative area and evacuated (step S301), and use of the sector in the alternative area instead of the adjacent sector is registered in the DMA so that the DMA is updated (step S302). Subsequently, the above-described first-class reduction processing is executed (step S303), and a mark in the failed sector is again read (step S304) so that data in the adjacent sector is restored (step S305).

When the data in the adjacent sector is normally restored (step S306: Yes), registration in the step S302 is

canceled to update the DMA (step S307), and the data registered in the alternative area is deleted (step S308). As a result, overuse of the alternative area is avoided.

On the other hand, if the data in the adjacent sector can not be restored (step S306: No), the read retry processing is terminated with registration in the step S301 and the step S302 being maintained. This guarantees normal reproduction including the data recorded in the adjacent sector.

Fig. 12 is a flowchart showing the fourth example of the read retry processing.

When the fourth example of the read retry processing shown in Fig. 12 starts, data in the adjacent sector is registered in the alternative area (step S401) and use of a sector in the alternative area in place of the adjacent sector is registered in the DMA so that the DMA is updated (step S402), as similar to the third example of the read retry processing shown in Fig. 13. Thereafter, the above-mentioned second-class reduction processing is executed (step S403), and a mark in the failed sector is again read (step S404). Subsequently, registration in the step S402 is canceled to restore the DMA (step S405), thereby completing the read retry processing.

As described above, in the second-class reduction processing, since the data in the adjacent sector is maintained, registration in the step S401 and the step S402 is seemingly unproductive. Abnormal termination may be,

however, caused due to interruption of power supply and the like during the second-class reduction processing. If registration in the step S401 and the step S402 has been executed, data on the information storage medium is safe even though such abnormal termination occurs. In other words, the fourth example of the read retry processing shown in Fig. 12 has very high safety of data.

Fig. 13 is a flowchart showing the fifth example of the read retry processing.

In the fifth example of the read retry processing shown in Fig. 13, data in the adjacent sector is registered in the alternative area (step S501), and use of a sector in the alternative area instead of the adjacent sector is registered in the DMA so that the DMA is updated (step S502). Thereafter, the above-described first-class reduction processing is executed (step S503), and a mark in the failed sector is again read (step S504). The procedure described thus far is completely the same as that of the third example of the read retry processing illustrated in Fig. 11, but the read retry processing is terminated without any change in the fifth example.

Since the adjacent sector is a sector generating strong cross talk which prevents a mark in other sector from being read, restoring data in this sector may again prevent the mark from being read. In the fifth example, therefore, the read retry processing is terminated with cross talk in the adjacent sector being reduced and with the adjacent

sector being substituted by the sector in the alternative area.

Fig. 14 is a flowchart showing the sixth example of the read retry processing.

5 In order to register data in the adjacent sector in the alternative area, data in the adjacent sector must be reproduced. It can be considered that data reproduction in the adjacent sector may be prevented by cross talk generated by a sector right next to that adjacent sector.

10 Therefore, in the sixth example of the read retry processing depicted in Fig. 14, starting from the failed sector from which a mark first failed to be read, mark reading is sequentially executed shifting to adjacent sectors until mark reading proves successful with respect to each of the outer peripheral direction and the central direction of the information storage medium (steps S600 and S610).

15 In the step S600, a number given to the failed sector from which a mark first failed to be read is determined as an initial value having a variable n. By
20 reducing the variable n by 10, a number indicative of a sector adjacent to the outer peripheral side is obtained (step S601), and a mark in the n-th sector is read (step S602). When mark reading has failed (step S603: No), control returns to the step S601 as long as a number of trial runs
25 for mark reading is within a predetermined value (step S604: Yes), and the similar procedure is repeated with respect to the sectors on the outer peripheral side. If a number of

trial runs for mark reading has exceeded the predetermined value (step S604: No), it is determined that normal mark reading is no longer possible and the read error processing is executed (step S605).

5 In the step S603, if it is determined that mark reading has been normally terminated, use of sectors in the alternative area is registered in the DMA in place of a series of sectors from a sector adjacent to the failed sector on the outer peripheral side to a sector from which normal reading has finally proved successful, and the DMA is updated (step S606). Mark reading, data evacuation and the first-class reduction processing are executed with respect to each of a series of these sectors (step S607). As a result, cross talk of all of these sectors is reduced.

10
15 In the step S610, the procedure similar to the step S600 is effected to a series of sectors which exist in a direction close to the center rather than the failed sector.

20 As described above, starting from the failed sector, data of a series of the sectors is evacuated in each of the outer peripheral direction and the central direction of the information storage medium, and cross talk of these sectors can be reduced.

25 Thereafter, a mark in the failed sector can be again read (step S620), and data of a series of the sectors is restored (step S630). Further, the DMA is also restored (step S640), thereby terminating the read retry processing.

 According to the sixth example of such read retry

processing, even if sectors generating strong cross talk are continuous, marks in the sectors can be normally read.

Although data in, e.g., the adjacent sector is evacuated to the alternative area in the foregoing embodiment, the information storage apparatus according to the present invention may evacuate data to a place other than the alternative area.

Further, laser power has been illustrated as power for writing a mark in the foregoing embodiment, but the power according to the present invention may be, for example, an intensity of a magnetic field.

Although the above embodiment has employed the optical storage type magneto-optical disk as the information storage medium, the information storage medium according to the present invention may be a magneto-optical disk adopting each storage mode such as magneto-optic recording, phase change recording and magnetic recording, or any other disk type storage medium such as an optical disk or a magnetic disk, or a card or tape type storage medium.

The region according to the present invention may be a sector illustrated in the foregoing embodiment, or a block consisting of a plurality of sectors, or multiple divided sectors.

As described above, according to the information storage apparatus of the present invention, a mark can be read without being disturbed by cross talk even if a track pitch is as narrow as 0.65 μm or lower.

If the technique according to the present invention is used, a mark can be normally read even though a track pitch is narrowed, thereby high density of the information storage medium can be advanced.

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211
2212
2213
2214
2215
2216
2217
2218
2219
2220
2221
2222
2223
2224
2225
2226
2